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Glen Goodwin
Chief, Thermo- and Gas-Dynamics Division
National Aeronautics and Space Administration
Ames Research Center
Moffett Field, California 94035

Abstract

Educational Demands in the Aerospace Age

By Glen Goodwin

The problems which a modern research and development laboratory are called upon to solve require both skilled theoreticians and experimentalists who are capable of understanding and utilizing very sophisticated experimental equipment. Many times measurements must be made in microseconds or nanoseconds where large interfering effects are present.

The recent graduate must be able to cope with these situations in order to achieve, without a long and painful learning period, a reasonable degree of professional advancement. The situation is a happy one if the student has been exposed to modern laboratory practices in his graduate work, but most often this is not the case. Modern experimental research equipment is costly and, in most cases, the very best equipment is the product of a long development period and may be unique to a particular research laboratory.

If some method could be found to bring the graduate student and University professor in close contact with the modern government or industrial laboratory and its staff, much valuable training and student motivation could be achieved.

It is the purpose of this paper to discuss a plan now in its embryonic stages at Ames Research Center to achieve some of these objectives. The paper will explain how an agreement has been worked out with three Universities, how it may be expanded, and how it can hopefully be advantageous to all parties involved.

Educational Demands in the Aerospace Age

By Glen Goodwin*

Introduction

The decision to send men to the moon in this decade required the rapid development of the technologies to support and make possible that exploration; this is being accomplished by a very rapid translation from ideas to realities. This requirement has led to a much closer relationship between the scientist and the engineer than has been achieved in the past, with the single exception of the development of nuclear weapons. It has also brought about a mutual understanding between the two groups and an appreciation of each others problems. In the realm of atmospheric-entry physics and technology, the marriage between scientist and engineer has been so complete as to render them almost indistinguishable. We have also rediscovered the old principle that experts in different disciplines working together can make amazingly rapid progress on the solution of complex problems. It is this principle and how it can be encouraged and strengthened within our educational system that will be the main topic of this paper.

The Interrelationship Between Theory and Experiment

To illustrate the foregoing point some examples will be given to show the advantages of utilizing theory and experiment together as compared to either approach alone. A dramatic illustration is provided by one of the first problems NASA faced some 10 years ago. We undertook

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*Chief, Thermo- and Gas-Dynamics Division, Ames Research Center, Moffett Field, California 94035.

the development of electric-arc heaters to heat air to the very high temperatures (more precisely "enthalpy") needed to simulate reentry into the earth's atmosphere at very high velocities. Figure 1 illustrates our progress in terms of stream enthalpy (and corresponding return velocity) achieved as a function of development time in years. During the first few years we depended upon intuition alone to guide our experimental efforts as theoretical guidelines were not available. Note our dismal progress during those early times! Finally, my colleague Howard Stine was able to develop a theory for energy and momentum transfer in one type of arc heater, consisting of a cooled tube with an electric current and air flowing longitudinally along the tube axis. We immediately patterned our electric arc heaters after his theoretical model. The change in progress after we had a theoretical model to guide the development is noteworthy. It is also noteworthy that this early theoretical model was approximate but capable of analytical solution in terms of the physical variable of the problem. Later on, with the aid of electronic computers, we were able to improve the theory greatly. The year the improved theory became available is also noted in figure 1.

Although a purely experimental approach is often unprofitable, a purely analytical approach to a physical solution can also come to grief if pertinent details of the physics are neglected. An example of this pitfall is shown in figure 2. A reentry vehicle in the shape of a blunt large-angle cone was required to enter the atmosphere with the conical nose forward since a heat shield could not be provided over the flat base region because of mission constraints. The center-of-gravity location was such that the vehicle was more stable flying base forward than nose forward. Also, the entry attitude was unknown and some method had to be found to turn the vehicle over to a nose-first attitude at a high altitude in order to avoid overheating the unprotected base region. Theory predicted that a method of accomplishing this maneuver was to put a small fence along half of the base. Indeed, an elegant theory was formulated to predict the force on the fence caused by the subsonic viscous flow downstream of the bow shock wave, as shown in figure 2. The theory, of course, predicted that the model would pitch upward as shown by the dashed arrow, but when the moments produced by this fence were measured in a hypersonic shock tunnel, the facts proved otherwise. The model pitched downward as shown by the solid arrow. The reason for this behavior was immediately apparent to all when photographs of the bow shock wave were examined. The fence had produced an inclined wave system over the half of the model containing the fence and had reduced the inviscid pressures over the base of the model in this region, while leaving the higher impact pressure produced by the nearly normal bow shock wave to act over the other half of the base, as shown by figure 3. Happily, the theory quickly incorporated this new bit of physics and is now able to predict the real situation with good accuracy.

These two examples were not picked at random nor is life always this simple, but they do illustrate the point that the experimentalist must understand the theoretical background of his problem and that theoretical work must account for all the important physical facts. It is very rare that both skills are present in a single individual and in order to obtain the needed close communication theorists and experimentalists should work in the same group or should have some means of day-to-day discussion.

Birds of a Feather Flock Together

There are strong forces at work which tend to separate people into groups of like disciplines. The ease of communication within a special area, the attraction of older recognized experts in a field for the younger members of the profession, and the increasing complexity of both theoretical and experimental work all contribute to this trend. There are certain advantages to this arrangement. Certainly, techniques are developed very expeditiously as a result of this grouping together, but many times the use of special new techniques for solving real problems is hampered.

In addition to the aforementioned reasons for specialists banding together, there is the increasing complexity and specialization of experimental equipment. In particular, the shock tubes, shock tunnels, plasma guns, and ballistic ranges, needed to simulate reentry flight speeds and their resulting high temperatures, have very short test times. Data are not only gathered in shorter and shorter tests, but an experimenter working with modern systems has plotted data in coefficient form presented to him from computer operated plotters within eight hours after a test. This state of affairs has many advantages to the mature experimentalist who understands the system and its limitations, but to the new graduate it presents a bewildering new world. The theoretician, unfortunately, tends to feel that such an elaborate system must surely yield the correct information and tends to believe the results without question.

Another bewildering situation confronts the recent graduate when he joins the modern aerospace laboratory staff; experimental equipment and its associated instrumentation are generally the result of lengthy development by the senior staff and are far from off-the-shelf items. The young graduate then faces the problem of a long period of familiarization often frustrating enough to send him back to the university to a life more familiar. The graduate interested in theory faces the specialist who has mastered the problem of solving coupled sets of differential equations, with complex nonlinearities and singularities, on a digital computer.

Laboratory-University cooperation may help solve these dilemmas of students. The transition between life at the university and membership in the modern industrial or government laboratory staff is eased by exposing the student to the outside laboratories during his graduate years. There are a number of NASA-university programs involving a very large number of universities and financed at the multimillion dollar level. These programs have been extremely successful and have been widely reported (see, for example, refs. 1 and 2). However, the purpose of this discussion is to describe a new program, now in its embryonic stage, which will not only complement existing programs but will perhaps help to solve the transition and other problems outlined in the foregoing part of this paper. This program is a series of work-study agreements between the NASA Research Centers and the universities in which each will hopefully benefit from their unique capabilities. Stripped of the legalistic authority contained in the Space Act which allows for this close cooperation, these work-study agreements are aimed at providing a mechanism whereby interested university scientists and their graduate students can work in close cooperation with their counterparts within the NASA Research Centers. Specifically, the university scientist and his fellow NASA scientist agree to work jointly on a project of mutual interest. The facilities, both theoretical and experimental, of the NASA Research Centers will be made available to the university, and the university laboratories and pool of talent will be made available to the NASA scientists on a mutually beneficial basis. It is strongly emphasized that the benefit from these agreements must be mutual or the program will not grow and prosper. While the agreements to work and study together are made as broad as possible, implementing specific projects will be left to the individual scientist concerned. The contacts, the extent of the cooperation on an individual project, will be left to the individual scientific workers. The exchange of monies to support each individual project will be handled as simply as possible in the form of small grants.

In essence, the agreement could permit the Center to make available to a university funds not to exceed a specified total amount per year for reimbursing out-of-pocket costs for conducting research of interest to both the Research Center and the university either at the university or at the Center using Center facilities by faculty members and appropriate students or technicians.

Each research effort must necessarily fit within a research program active at the Center and would be supported at an appropriate level in a given year, and would be the joint responsibility of the faculty member proposing it and his NASA counterpart. Students working therein would serve an internship under this faculty advisor.

In addition, the Center would make available at the universities, request certain senior research scientists to participate in the teaching programs of the university. This might have the added advantage of freeing university faculty to devote additional time to research. It could also bring to the universities, in certain specialized areas, talent not now available.

The university would make available to the Center a pool of research talent that would bolster NASA research effort, while at the same time extending the research facilities and opportunities in advanced research areas of the physical and life sciences to the faculty and students.

An example of the pertinent parts of an agreement now active between one midwestern university and Ames Research Center is given in the following paragraphs. This example was worked out to fit the particular desires of the Center and of that university and should be regarded only as typical.

THE RESEARCH CENTER AGREES:

1. to arrange, in response to requests from the University, meetings with scientists, and other professional personnel employed or engaged in work at the Research Center; Provided, however, that all such meetings shall be scheduled at reasonable times and hours and in no event shall such meetings adversely interfere with the activities and functions of the Research Center or personnel thereof;

2. to furnish in response to requests from the University, and at no charge, access to library, laboratory, or other facilities at the Research Center during reasonable times and hours, and, moreover, to permit the University to use, at no charge, a reasonable amount of office, laboratory, or other space at the Research Center if such space is available; Provided, however, that the Research Center may terminate such use upon notice in writing forwarded to the University not less than one month in advance of the date of termination;

3. to reimburse, in whole or in part, but only on written demand by the University, costs for the use of University services, equipment, personnel, and facilities for those projects, programs, or activities, if any, mutually agreed to, and undertaken by the parties at the specific written request of the Research Center communicated to the

University in advance of the undertaking involved; Provided, however, that any arrangements for reimbursement shall be subject to the terms, conditions, and limitations set forth and agreed upon as part of this agreement;

4. to make available at the facilities or field projets of the Research Center including the laboratories thereof useful work experience, in basic and applied research, for personnel matriculated at the University and furnished to the Research Center, who have been qualified by the University to undertake work-study as authorized under the federal College Work-Study Program; And, moreover, the Research Center shall be deemed the employer of any person so furnished; Except that none shall be considered an employee of the Federal Government within the meaning of laws administered by the United States Civil Service Commission. The ultimate right to control and direct the work of all such persons shall devolve upon the Research Center;

5. to contribute a share of the compensation payable to each of the University personnel who are authorized to work under the control and direction of the Research Center incident to the federal College Work-Study Program, and to compensate the University for unreimbursed administrative costs related thereto consonant with the terms, conditions, and limitations set forth in this agreement; Provided, however, that the Research Center shall have access, at any time, to relevant records of the University so as to assure the appropriateness of payments made for these purposes;

THE UNIVERSITY AGREES:

6. to make available for projects of mutual interest, the use of services, equipment, personnel, and facilities controlled by the University,; but availability of the same shall be consistent with, and shall not be

permitted to impede, the functions, interests, and activities of the University. University personnel who are so utilized, or who otherwise provide services including, by way of description and not limitation, participants in the "on-campus" segment of the federal College Work-Study Program, shall be controlled and directed in their work, or research, by the University.

7. to permit, strictly on a space-available basis, and at no charge, federal employees selected by the Research Center to attend classroom or other lectures conducted under the auspices of the University, but no such person shall be enrolled by the University as either a student or auditor or otherwise be considered as admitted to the University for any purpose;

8. to publicize at the University the matters concerning this Agreement, including opportunities available to authorized participants "on-campus" and "off-campus" under the provisions of the federal College Work-Study Program;

9. to furnish support personnel, of the type and in the numbers, requested by the Research Center for purposes of administering the matters contemplated by this Agreement, and, in such event, the University shall be reimbursed for the costs involved subject to the terms, conditions, and limitations of this agreement. Where feasible, but at the sole discretion of the University, and if otherwise consistent with law, support personnel may be obtained, but only for work at the University, from enrollees in the Neighborhood Youth Corps consonant with the authority contained in Title 1-B of the Economic Opportunity Act of 1964, as amended, 42 U.S.C. 2731 et. seq.;

10. to permit University personnel, notwithstanding any other provision of this Agreement, to donate, without condition, a gift of their services to the National Aeronautics and Space Administration if such donation does not adversely interfere with, or impede, the functions or activities of the University; Provided, however, that the proffer of such unconditional donation of services, before commencing performance thereof, is first accepted in writing by competent federal authority, and is otherwise consistent with Subsection 203(b)(4) of the National Aeronautics and Space Act of 1958, as amended, together with regulations in implementation thereof;

BOTH PARTIES AGREE:

11. that persons, agents, and servants connected with either party may enter the premises and facilities of the other for purposes of administering matters arising under this Agreement or otherwise discharging the terms thereof; However, a party may be required to remove from the premises or facilities of the other party any person, agent, or servant connected with the former who is careless, insubordinate, or otherwise objectionable, and such request for removal shall be final and conclusive and not subject to appeal. Moreover, at the sole discretion of the Research Center access to all, or any part of, facilities at the Center, for reasons of national security or otherwise, may be barred to any person connected with either of the parties hereto, and the decision by the Research Center to deny access shall be final and conclusive and not subject to appeal;

12. that rights, if any, in the federal Government to inventions made by University personnel, including students, in the performance of work contemplated by this Agreement shall be determinable by recourse either to Subsection 305 of the National Aeronautics and Space Act of

1958, as amended, or Executive Order 10096, as amended by Executive Order 10930, together with federal regulations in implementation thereof, and the Patent Counsel of the Research Center shall be available to either party for advice and guidance in this regard. Rights and obligations involving data and copyrights are determinable by recourse to Schedule P annexed hereto and made a part hereof.

13. that the Assistant Director for ___________, NASA-Ames Research Center and the ___________ University are the respective authorized representatives of the Director of the Research Center and the President of the University in connection with all matters pertaining to, or arising under, this Agreement. Each of the said authorized representatives, upon notice in writing communicated in advance to the other, may re-delegate, in whole or in part, his authority arising under this Agreement.

The foregoing excerpts from the agreement outline a mechanism whereby the Center scientist and his university counterpart may collaborate to the benefit of both groups. We hope that this program will be expanded. In order to be fruitful, its expansion must proceed slowly, and will depend for its success upon the motivation of the individual scientists themselves and upon their sincere desire to accomplish this cooperation.

References

1. T. L. K. Smull, The Nature and Scope of the NASA University Program, NASA SP-73, 1965.

2. Donald J. Montgomery, Summary Report on the NASA University Program Review Conference, NASA SP-81, 1965.

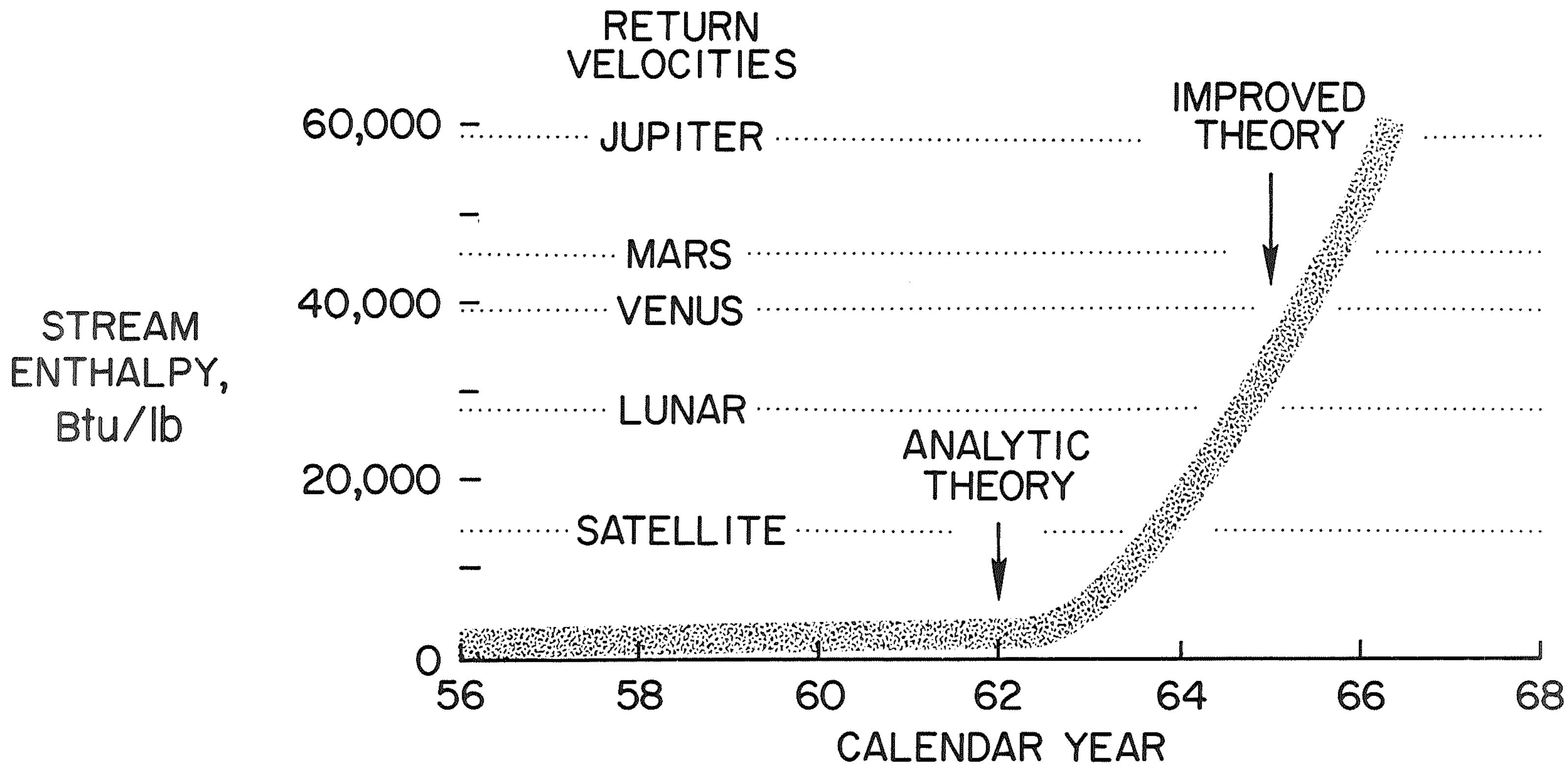

Figure 1.- Electric-arc heater development.

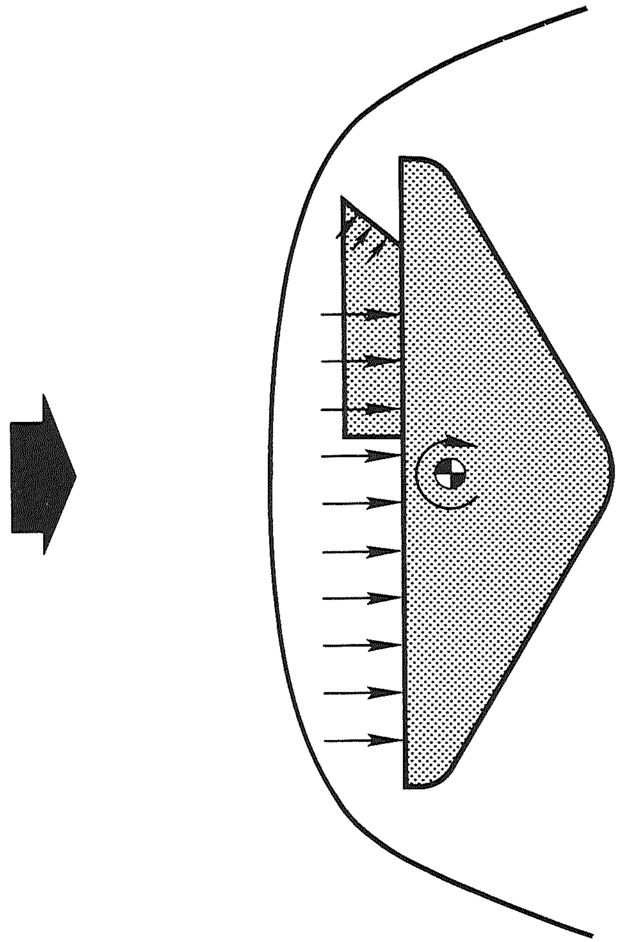

Figure 2.- Theoretical pressures.

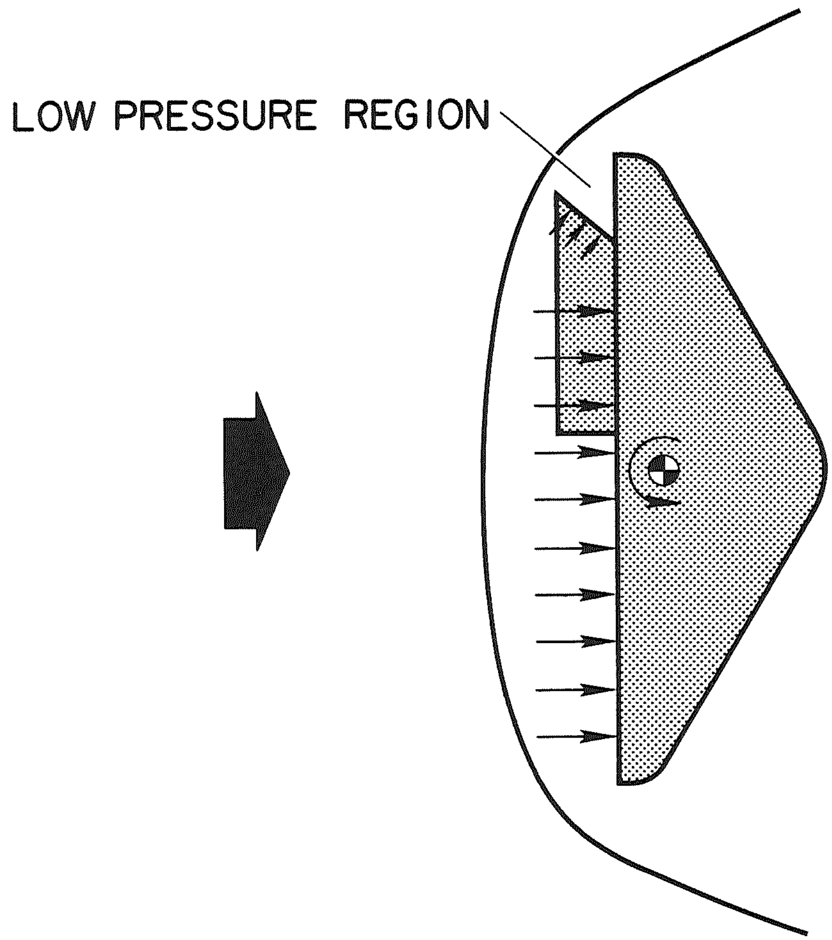

Figure 3.- Experimental pressures.